Features of Heart Rate Variability Capture Regulatory Changes During Kangaroo Care in Preterm Infants

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Objective To determine whether heart rate variability (HRV) can serve as a surrogate measure to track regulatory changes during kangaroo care, a period of parental coregulation distinct from regulation within the incubator.

Study design Nurses annotated the starting and ending times of kangaroo care for 3 months. The pre-kangaroo care, during-kangaroo care, and post-kangaroo care data were retrieved in infants with at least 10 accurately annotated kangaroo care sessions. Eight HRV features (5 in the time domain and 3 in the frequency domain) were used to visually and statistically compare the pre-kangaroo care and during-kangaroo care periods. Two of these features, capturing the percentage of heart rate decelerations and the extent of heart rate decelerations, were newly developed for preterm infants.

Results A total of 191 kangaroo care sessions were investigated in 11 preterm infants. Despite clinically irrelevant changes in vital signs, 6 of the 8 HRV features (SD of normal-to-normal intervals, root mean square of the SD, percentage of consecutive normal-to-normal intervals that differ by >50 ms, SD of heart rate decelerations, high-frequency power, and low-frequency/high-frequency ratio) showed a visible and statistically significant difference ($P < .01$) between stable periods of kangaroo care and pre-kangaroo care. HRV was reduced during kangaroo care owing to a decrease in the extent of transient heart rate decelerations.

Conclusion HRV-based features may be clinically useful for capturing the dynamic changes in autonomic regulation in response to kangaroo care and other changes in environment and state. *(J Pediatr 2017;182:92-8).*

Kangaroo care refers to a period of direct skin-to-skin contact in which infants are placed in the prone position on a parent's naked chest. Kangaroo care is considered safe and has been reported to reduce morbidity and mortality, even in extremely preterm infants.[1,2] It is associated with important physiological benefits, including promoting quiet sleep, enhancing thermoregulation, and reducing crying/fussy behavior,[3] and can mitigate physiological responses to procedural pain.[4,5] This indicates that parental coregulation is superior to regulation within the incubator environment, and that kangaroo care positively influences autonomic regulation.[6] The ability to track and quantify any changes that occur as a result of kangaroo care may aid in detecting and establishing patterns of improved regulation in preterm infants and may offer opportunities to enhance neurodevelopmental care and homeostatic regulation.

The role of the autonomic nervous system in controlling homeostatic regulation can be evaluated by tracking cardiorespiratory variables, including heart rate (HR), respiratory rate (RR), oxygen saturation (SpO_2), and temperature. Previous studies have shown that these variables remain stable during kangaroo care,[7] supporting the conclusion that kangaroo care is safe; however, this finding in itself does not provide insight into the underlying physiological changes triggered by kangaroo care.

The physiological phenomenon of HR variability (HRV, defined as the variation in intervals between consecutive heartbeats) can provide additional

ECG	Electrocardiography
HF	High frequency
HR	Heart rate
HRV	Heart rate variability
LF	Low frequency
NICU	Neonatal intensive care unit
NN	Normal-to-normal
pDec	Percentage of decelerations
pNN50	Percentage of consecutive normal-to-normal intervals that differ by >50 ms
PSNS	Parasympathetic nervous system
RMSSD	Root mean square of the standard deviation
RR	Respiratory rate
SDDec	Standard deviation of deceleration
SDNN	Standard deviation of normal-to-normal
SNS	Sympathetic nervous system
SpO_2	Oxygen saturation

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physiological insight into these regulatory changes. HRV reflects the dynamic, rapidly occurring changes in autonomic regulation caused by the primary systems controlling the HR. In addition to humoral factors, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS) can influence HR instantly, that is, from beat to beat.[8,9] Multiple features analyzing these beat-to-beat changes have been constructed and studied in adults, with at least some consensus regarding their interpretation. For instance, the SD of the R-R peak intervals reflects overall variability, whereas differences in successive R-R intervals largely reflect PSNS activity.[8]

HRV has been less thoroughly explored in neonates, however. Moreover, the behavior of the neonatal heart, particularly in the premature neonate, is significantly different from that of the adult heart, reflecting underlying differences in autonomic regulation. This suggests that interpretations of HRV-based features in neonates may differ from those of adults.[9,10] For example, unlike adults, neonates display a significantly larger range of variation in HR and RR and are prone to both acute tachycardia and bradycardia,[9,11] suggesting that HRV features should account for this intrinsically different aspect of neonatal physiology.

Although kangaroo care has been shown to enhance autonomic maturation,[12] to date few studies have examined the dynamic changes in HRV during kangaroo care, notably without consensus on the findings.[13,14] No studies have visualized changes in HRV during kangaroo care and compared it with HRV while the neonate was in the incubator.

We hypothesized that regulatory changes in preterm infants can be captured using HRV-based features. We used HRV-based features to track regulatory changes that occur as a result of kangaroo care, a period of improved regulation. We also analyzed HR, RR, SpO2, and temperature to provide a holistic perspective on regulation.

Methods

The Máxima Medical Center has an 18-bed, level III, tertiary neonatal intensive care unit (NICU) with private rooms in which kangaroo care is practiced routinely. Parents are encouraged to perform kangaroo care for durations of 60 minutes or longer. Routine patient monitoring continues during kangaroo care, including electrocardiography (ECG), HR, RR (using impedance pneumography), SpO_2, and temperature (measured in the diaper). The patient monitors (IntelliVue MX 800; Philips, Hamburg, Germany) have the provision to save the variable data (HR, RR, SpO_2, and temperature; 1 value every minute) and the 3-lead ECG data (sampled at 125 Hz) of the past 72 hours of measurement. Notably, ECG sampled at 125 Hz has proven to be sufficient for determining HRV-based features.[15] For this study, nurses annotated all kangaroo care sessions by recording the start time (placement on parental chest) and the end time (placement into the incubator) of kangarooing for each session over a 3-month period between August and October 2015.

This study was part of a comprehensive observational perinatal monitoring research program (IMPULS 1) conducted at the Máxima Medical Center, in collaboration with Eindhoven University of Technology and Philips Research. Approval was provided by the local Ethical Committee. We selected neonates with more than 10 annotated kangaroo care sessions within the study period, to account for intrapatient variability and maturational differences. This yielded a total of 220 kangaroo care sessions from 11 neonates (6 males and 5 females). We excluded kangaroo care sessions in which infants were mechanically ventilated or diagnosed with an infection, a congenital anomaly, or a severe brain pathology (periventricular leukomalacia or intraventricular hemorrhage grade III/IV). In addition, the kangaroo care sessions had to last 1 hour or longer, have data for at least 1 hour in the pre-kangaroo care and post-kangaroo care periods, and not overlap with the post-kangaroo care/pre-kangaroo care period of another kangaroo care session within the same infant. **Table I** characterizes the patient metadata at birth (first 2 rows) and across the kangaroo care sessions in this study.

To observe regulatory changes in infants as a result of kangaroo care, we compared HRV features visually and statistically for the pre-kangaroo care and during-kangaroo care periods. For the purpose of visualization, we chose to retrieve data for the 60 minutes before kangaroo care, for the variable duration of kangaroo care, and for the 60 minutes after kangaroo care. Because the duration of kangaroo care was variable, but at least 60 minutes long, the first 30 minutes and the last 30 minutes of each kangaroo care session were retained for visualizations (**Figure 1**).

For statistical analyses of variable data (vital signs) and HRV features, stable epochs were determined in the pre-kangaroo care and during-kangaroo care periods (**Figure 1**). We determined that the first 30 minutes of the pre-kangaroo care epoch are stable, whereas in the last 30 minutes, nursing care events, such as diaper changes, occur with or without parental assistance. The period of kangaroo care itself was assumed to be stable after 15 minutes, allowing for the decay of any physiological changes arising from the transition. Therefore, the first 30 minutes of the pre-kangaroo care period were compared with the 30-minute epoch in between the 16th and 45th minutes of kangaroo care (displayed as the 76th-105th minutes

Table I. Patient characteristics at birth and on the days corresponding to kangaroo care sessions

Characteristics	Median	25th percentile	75th percentile
Gestational age, wk	28.3	26.2	29.0
Birth weight, g	950	836	1273
Kangaroo care sessions, n	9	9	24.2
Duration of kangaroo care sessions, min	83	70	106.5
Interval between the first and the last kangaroo care sessions, d	16	10.5	30
Postmenstrual age during first kangaroo care session, d	28.6	27	29.6
Postmenstrual age for all kangaroo care sessions, d	30.1	28.7	31.1
Postnatal day for all kangaroo care sessions	18	10	24.2